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14. ABSTRACT
This Test Operations Procedure provides procedures for determining the field of fire for vehicle-mounted primary and secondary armament. This includes maximum elevation and depression angles at all traverse positions; maximum traverse angles for continuous traverse; and minimum range of anti-personnel fire at all positions of traverse.

15. SUBJECT TERMS
Turning circle, Stadia rod, ground intercept point, lateral angle.

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US ARMY DEVELOPMENTAL TEST COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 3-2-813 16 December 2009
DTIC AD No.

FIELD OF FIRE

*This TOP supersedes TOP 3-2-813 dated 22 March 1985

1. SCOPE.

1.1 Purpose.

This Test Operations Procedure provides procedures for determining the field of fire for vehicle-mounted primary and secondary armament. This includes maximum elevation and depression angles at all traverse positions; maximum traverse angles for continuous traverse; and minimum range of anti-personnel fire at all positions of traverse.

1.2 Background.

Field of Fire (FOF) is defined as the area which a weapon or group of weapons can cover effectively with fire from a given position. FOF is an important factor in determining the effectiveness of combat vehicles. FOF is restricted by such factors as mechanical interference and limits of gun movement; limitations of physical movement of the operator in using available field of fire; zones of firing interference where line of fire intersect the vehicle; and suitability of limit switches, firing interrupters, and automatic devices to divert the gun from interference areas.

1.3 Limitations.

These procedures can be utilized for attaining Field of View (FOV) measurements of all crew positions of a combat vehicle with the understanding that the measurements will be limited by natural head and eye rotation limits.

2. FACILITIES AND INSTRUMENTATION.

a. A turning circle.

b. Two stadia rods, or some instrument that provides measurement references from the ground to above the horizontal line of sight of the user.

c. Tape measure.

d. Laser pointer.

e. Inclinometer (digital protractor).

f. Ammunition boxes.

g. Sights and mounts.

3. REQUIRED TEST CONDITIONS.

3.1 General.

a. Location. Testing must be performed on a level area such as a large concrete turning circle. The radius of the turning circle should be larger than the length of the vehicle under test. Mark the circle with radial lines from the center point of the circle outward at 10 degree intervals.

b. Mounting. Mount all primary and secondary armaments together with dummy ammunition, ammunition boxes, feed chutes, ejection heads and chutes, spent cartridge and link containers, sights and sight mount.

c. Orientation. Position the vehicle such that the longitudinal axis of the front partition of the vehicle is aligned with the 0 degree marker of the turning circle. Place the gun's traverse center of rotation over the center of the turning circle so that the gun is at a 0 degree reference azimuth and points directly at a 0 degree reference marker on the turning circle.

d. Measurements. Measurements should be taken in 10 degree intervals. Measurements taken which are at intervals less than the designated 10 degree intervals shall be interpolated.

e. Limits/Stops. Ensure that manual and power gun control systems operate properly and that limit switches are properly adjusted.

f. Sighting. Remove the firing mechanism from the main gun to permit sighting through the firing pin hole. Inject the laser pointer into the pin hole.

3.2 Pre-test.

a. Use tape measure to measure the height of the gun's traverse center of rotation The dimensions of the vehicle should also be taken as well as the relative distance of the gun's transverse center of rotation from the front and side of the vehicle.

4. TEST PROCEDURES.

4.1 Gun Traverse Test.

Determine gun traverse angles at full elevation and depression for weapons 20mm and larger using manual force and electrical/hydraulic control (when applicable) by the following procedures:

a. Place the gun at maximum allowable elevation by manual control. Measure the angle with the inclinometer. Record items that prevent further elevation. If the item involved is a mechanical elevation stop, determine the additional elevation angle that can be obtained by its removal. When the limiting factor is mechanical interference, determine if a mechanical stop is required to protect the interfering component of the gun.

b. While at maximum elevation traverse the gun through a 360 degree lateral rotation or maximum possible rotation of the turret. Record any change in the maximum elevation. Identify the points of mechanical elevation interference. This includes noting the traverse angles through which interference with the line of fire occurs. Interference is typically caused by vehicle components that would be struck by gun projectiles and the reduction of available angles caused by restraint of body movement of the operator. Observe limitations upon handling the weapon when it is at maximum elevation.

c. Depress the gun and note any tendency to stick or bind as it departs from maximum elevation.

d. Place the gun at maximum allowable depression by manual control. Measure the angle with an inclinometer. Record items that prevent further depression. If the item involved is a mechanical depression stop, determine the additional depression angle that can be obtained by its removal. When the limiting factor is mechanical interference, determine if a mechanical stop is required to protect the interfering component of the gun.

e. Traverse the gun through a 360 degree lateral rotation or maximum possible rotation of the turret. Record any change in the maximum depression. Identify the points of mechanical depression interference. This includes noting the traverse angles through which interference with the line of fire occurs. Interference is typically caused by vehicle components that would be struck by gun projectiles and the reduction of available angles caused by restraint of body movement of the operator. Observe and record limitations upon handling the weapon when it is at maximum depression. Observe whether electrical or hydraulic connections limit the ability of the gun to traverse 360 degrees.

f. Elevate the gun and note any tendency to stick or bind as it departs from maximum depression.

NOTE: For guns with limited traverse, less than 360 degrees, conduct procedures “a” through “f”. Record the maximum traverse available. Angles of traverse shall be measured by using the radial reference markers on the turning circle.

g. Place the gun at full elevation by power control. Measure the elevation angle.

h. Place the gun at full depression by power control. Measure the depression angle.

4.2 Minimum Ranges of Fire.

a. Place the gun at full depression, aimed over the front of the vehicle at the 0 degree reference point.

b. Using the stadia rod, determine where the projected laser light beam intersects the surface of the turning circle. If the surface of the turning circle is not visible at the stadia rod distance then record the stadia rod reading and calculate the ground intercept.

c. Traverse the gun through a lateral 360 degree rotation. The projected laser light beam will define the circular path concentric with the turning circle (using the stadia rod as a target for laser) except when interference with gun movement or obstructions in the line of fire occurs. When necessary, elevate the gun to clear interference. Record the depression angle and azimuth angle.

d. Define the appropriate projected points of interference by the stadia rod readings taken at the corners of the interfering object.

e. Transfer the interference points to a polar plot using the angle of azimuth angle and the calculated ground intercept. To calculate the ground intercept (G_i) divide the gun's height from ground (G_r) by the Sine of the measured depression angle. The equation yields:

$$G_i = G_r / \sin \Theta$$

If the depression angle can not be measured with an inclinometer, it can be calculated by looking at the FOF projection as a right triangle. The vertical distance between the ground and the gun's position is the height of the triangle. This distance represents the gun's reference distance. The horizontal distance from the center of origin out to the point where the shot line makes contact with the ground represents the ground distance (G_d). The ground intercept is the segment that connects the two lines. When the values of both distances are known the depression angle can be solved using the Arctangent of the gun's reference distance over the ground distance.

$$\Theta = \arctan (G_r / G_d)$$

If the ground is not visible and a stadia rod reading must be taken the process will be slightly altered. The stadia rod reading (S_r) must be subtracted from the gun's reference distance. This new calculation will serve as the height of the triangle. The horizontal distance from the center of origin to the stadia rod (S_d) will serve as the base of the triangle. Although the triangle is different in size the angle remains the same. This yields

$$\Theta = \arctan ((G_r - S_r) / S_d)$$

where S_r is the stadia rod reading and S_d is the stadia rod distance from the center of the origin.

d. Plot the polar coordinates using the ground intercept as the radius and the lateral angle as the angular coordinate.

5. DATA REQUIRED.

5.1 Gun Traverse Test.

a. Elevation Check. The following data shall be recorded:

(1) Maximum elevation angle.

(2) Items that prevent further elevation.

(3) Maximum elevation angle obtainable with mechanical stop removed, when applicable.

(4) Changes in maximum allowable elevation angle for continuous or limited traverse guns, and traverse angle location.

(5) Location, elevation, and traverse angles in which:

(a) Interference with line of sight and the vehicle components that would be struck by projectiles.

(b) Reduction of available angles caused by crew movement restraints.

(6) Tendency of gun to stick or bind when depressed.

b. Depression Check. The following data shall be recorded:

(1) Maximum depression angle.

(2) Items that prevent further depression.

(3) Maximum depression angle obtainable with mechanical stop removed, when applicable.

(4) Changes in maximum allowable depression angle for continuous or limited traverse guns, and traverse angle location.

(5) Location, depression, and traverse angles in which:

(a) Interference with line of sight and the vehicle components that would be struck by projectiles.

(b) Reduction of available angles caused by crew movement restraints.

(6) Tendency of gun to stick or bind when elevated.

c. Power Elevation/Depression Check. The following data shall be recorded:

(1) Maximum elevation angle.

(2) Maximum depression angle.

(3) Adequacy and performance of limit switches.

d. Record electrical or hydraulic connection interference.

e. Photographs. Photographs of the test vehicle, its weapon system configuration, and any obstructions that are present should be taken.

5.2 Minimum Ranges of Fire.

Record, when applicable, the inclinometer's readings. Record stadia rod reading and extrapolate out to the ground intercept.

6. PRESENTATION OF DATA.

Field of Fire data shall be plotted on polar graphs with the FOF shown from the gun's reference position (see Figure 1). Because the polar plot does not define the dimensions of the interference points a second vertical plot is required. This plot illustrates the depression/elevation angle required to clear the interference point based on the azimuth angle of the gun (see Figure 2) Because there are several calculations that can be made, it is recommended that an Excel spreadsheet be created to do the calculations. Figure 3 is a template of an Excel sheet used to record data.

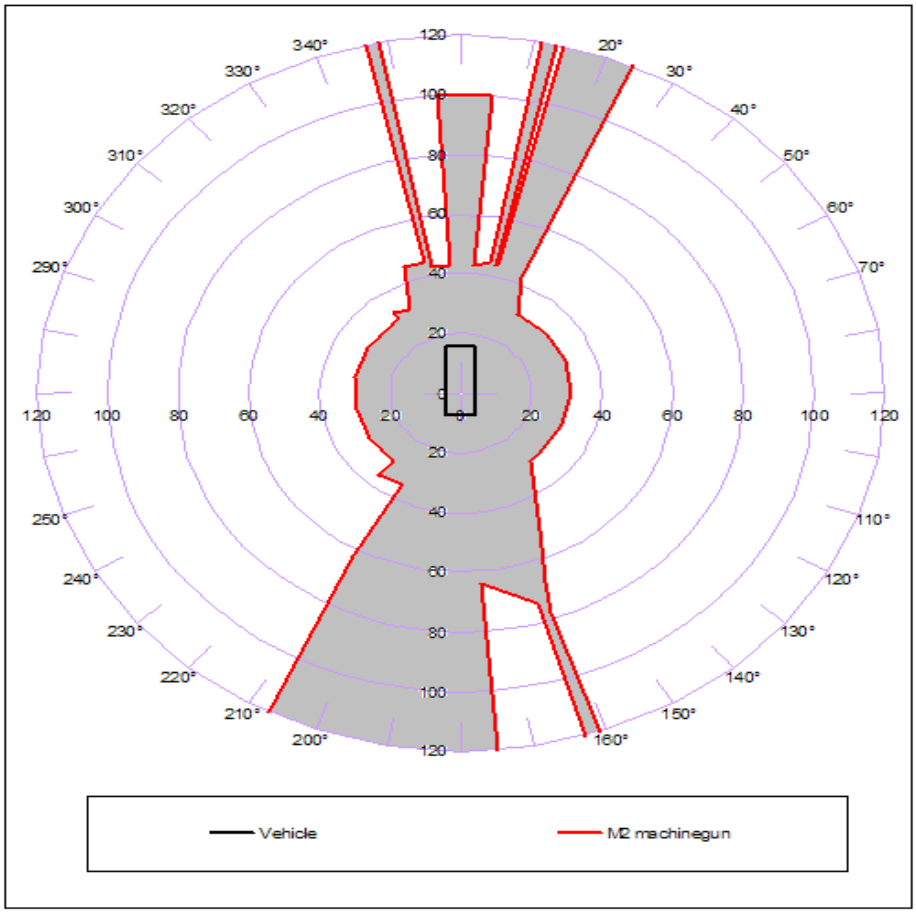

Figure 1. Polar Plot of Field of Fire (Ground Intercept).

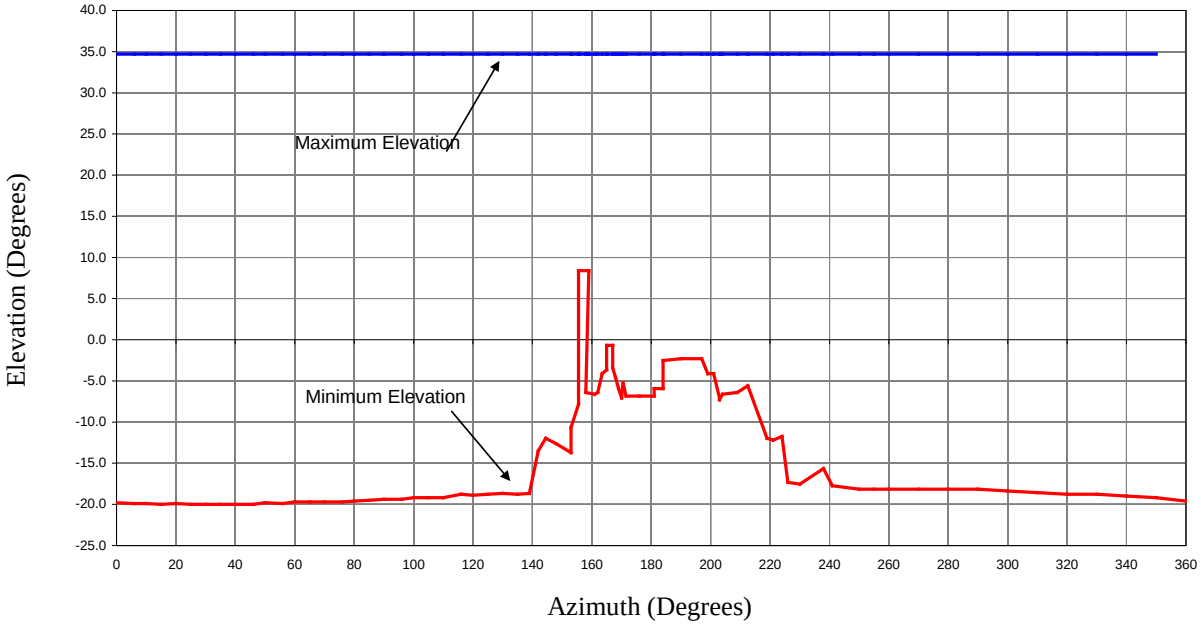

Figure 2. Field of Fire Plot (Azimuth versus Elevation).

FOV/FOF

	feet		feet
Eye Height:		Max radius:	120
Stadia distance:		Interval:	20
vehicle width:		Trailer	
vehicle length:		Trailer width:	
drivers position width:		Trailer length:	
drivers position length:		Trailer gap:	

input field

Window (placement)	stadia height (ft)	(in)	Cone (ft)	Angle (deg)		ground distance (ft)		X	Y

Figure 3. Excel Template.

APPENDIX A. GLOSSARY.

Arctangent: mathematical function that produces the visual angle of declination when provided an eye height and ground distance.

Ground distance: the horizontal distance from the center of origin out to the point where the ground intercept makes contact with the ground.

Stadia Rod: a graduated wooden or aluminum rod, the use of which permits the determination of differences in elevation.

APPENDIX B. ABBREVIATIONS.

Arctan	=	Arctangent
FOF	=	field-of-fire
G*r*	=	gun's height from ground
G*d*	=	ground distance
G_i	=	ground intercept value
MIL-STD	=	Military Standard
S_d	=	stadia rod distance from the center of the origin
S_r	=	stadia rod reading
TOP	=	Test Operations Procedure
Θ	=	visual angle of declination

APPENDIX C. REFERENCES.

For information only:

a. Military Standard (MIL-STD) 1472F, Department of Defense Design Criteria Standard, Human Engineering, 23 August 1999.

b. SAE Standard J1050, Surface Vehicle Recommended Practice Measuring the Driver's Field of View, January 2003.

Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Test Business Management Division (TEDT-TMB), US Army Developmental Test Command, 314 Longs Corner Road Aberdeen Proving Ground, MD 21005-5055. Technical information may be obtained from the preparing activity: US Army Aberdeen Test Center (TEDT-AT-WFS), 400 Colleran Road, Aberdeen Proving Ground, MD 21005-5059. Additional copies can be requested through the following website: http://itops.dtc.army.mil/RequestForDocuments.aspx, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.